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(54) **Method of supplying reactant gas to a substrate processing apparatus**

Verfahren zum Einleiten reaktiven Gases in eine Substratbearbeitungsvorrichtung

Méthode d'introduire de gaz réactif dans un appareil de traitement de substrats

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(56) References cited:
EP-A- 0 473 067 **US-A- 4 223 048**
US-A- 4 982 753

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Description

[0001] This invention relates to a method of supplying two different processing gases to a semiconductor wafer processing chamber.

[0002] Present day equipment for the semiconductor industry is moving toward single substrate processing because processing chambers can be made smaller and processing can be better controlled. Further, modern semiconductor vacuum processing systems have been developed to carry out more than one processing step on a substrate without removing the substrate from a vacuum environment. The use of such vacuum systems results in a reduced number of particulates that contaminate the surface of the wafer during processing, thereby improving the device yield.

[0003] A typical example of a modern CVD processing apparatus is shown in Fig. 1. In this figure a single substrate reactor 10 is shown to include a top 12, side walls 14 and a lower portion 16 that together define a chamber 18 into which a single substrate, such as a silicon wafer 20, can be loaded. The wafer 20 is mounted on a susceptor 22 that can be rotated by a drive 23 to provide a time averaged environment for the wafer 20 that is cylindrically symmetric.

[0004] A preheat ring 24 is supported in the chamber 18 and surrounds the susceptor 22. The wafer 20 and the preheat ring 24 are heated by light from a plurality of high intensity lamps, schematically indicated as 26, mounted outside of the reactor 10. The top 12 and lower portion 16 of the reactor 10 are typically made from clear quartz which is transparent to the light from lamps 26. Quartz is generally used to make up the top 12 and lower portion 16 because it is transparent to light of both visible and IR frequencies; it exhibits a relatively high structural strength; and because it is chemically stable in the process environment of the chamber.

[0005] During the deposition process, processing gas (whether reactant or dopant) is supplied to the interior of the chamber 18 from an exterior source, schematically represented by two tanks 28. The gas flows from the gas supply 28 along a gas supply line 30 and into the chamber 18 via a gas inlet port 32. From the port 32 the gas flows across the preheat ring 24 where it heats up, across the susceptor 22 and wafer 20 in the direction of the arrows 34 to be evacuated from the chamber 18 through evacuation port 36. The dominant shape of the flow profile of the gases is laminar from the gas input port 32 and across the preheat ring 24 and the wafer 20 to the exhaust port 36 even though the rotation of the wafer 20 and thermal gradients caused by the heat from the lamps 26 do affect the flow profile slightly.

[0006] The above described CVD processing chamber can accommodate a number of different processes can take place. Each process differs depending on the desired end result and has different considerations associated therewith.

[0007] In the polysilicon deposition process, doped or

undoped silicon layers are typically deposited onto the wafer using processes such as low pressure chemical vapor deposition (CVD). In this process a reactant gas mixture including a source of silicon (such as silane, disilane, dichlorosilane, trichlorosilane or silicon tetrachloride) and optionally a dopant gas (such as phosphine, arsine, or diborane) is heated and passed over the wafer to deposit a silicon film on its surface. In some instances a non-reactant, carrier gas such as hydrogen, is also injected into the processing chamber together with either or both of the reactant or dopant gases. In this process, the crystallographic nature of the deposited silicon depends upon the temperature of the deposition. At low reaction temperatures, the deposited silicon is mostly amorphous; when higher deposition temperatures are employed, a mixture of amorphous silicon and polysilicon or polysilicon alone will be deposited.

[0008] One problem with the doped polysilicon deposition is that the temperature dependence of dopant incorporation is opposite to the temperature dependence of the polysilicon deposition rate. Adjusting the temperature to obtain thickness uniformity in the polysilicon layer produces a non-uniform dopant incorporation. The dopant gas has, in the past, been incorporated in the processing gas before it is injected into the chamber, and there was therefore no control of the dopant gas flow independent of the flow of the silicon species processing gas.

[0009] In another process, the nitride deposition process, a stream of reactant gas, which is a mixture of ammonia (NH_3) and any one of the various silane species, is injected into the chamber. These two gases react at room temperature to produce small crystals. In the arrangement shown in Fig. 1 the gas storage 28 is shown to include two tanks, both of which feed into a single supply line 30. If these tanks contained ammonia and silane respectively, and the line 30 were at room temperature, this reaction would occur and particles would form along the entire length of the supply line 30 and within the manifold 32. These particles are undesirable as they are a source of contamination in the chamber 18 and their existence should therefore be eliminated.

[0010] In addition, it has been found that some reactant gases pass through the gap between the preheat ring 24 and the susceptor 22. This causes deposition on the back side of the susceptor 22 and on some of the other components in the lower portion of the chamber 18. Such deposition is both wasteful and undesirable as it requires additional cleaning to remove.

[0011] US-A-4223048 discloses a plasma enhanced chemical vapour processing apparatus for processing semiconductive wafers and including an elongate tube having end caps. Gases to be employed in the chemical vapour processing apparatus are connected to the chamber by tubes and flow controllers. The flow controllers feed respective manifolds which are connected to radially directed flow passages located in diametrically opposed relation in one of the end caps and feeding into

a central recess formed in the end cap where the mixed gases flow into the tube.

[0012] US-A-4982753 discloses a wafer cleaning, etching and stripping apparatus including a bowl, a table in the bowl carrying a cassette of wafers, and a spray post with multiple fluid passages and ports directing fluid spray against the wafers. The spray post defines passages which in turn are connected respectively to numerous sets of first second and third ports. The passage connected to one port is in turn connected to a source of processed material such as acid. The other passages are connected in turn to the other ports which are connected by oscillator mechanisms to a source of gas such as nitrogen. In use, processed material flows continuously through said one port and flow from each of the other ports alternates in an on-off manner, mixing taking place within the spray post.

[0013] EP-A-0473067 discloses a wafer processing reactor having an input manifold to enable control of a process gas flow over a wafer that is being processed. The gas supply manifold supplies a pair of different gases, one of the gases being supplied from a first gas source to a first pipe and a second gas being supplied from a second gas source to a second pipe. Each of the two pipes splits into seven pipes, each provided at one of a set of inlets to a different channel of the gas inlet port. The reactant gas is directed to the upper part of the chamber only. Indeed an additional gas, such as hydrogen or nitrogen is injected into the bottom half of the chamber to prevent reactant gas from flowing into this part of the chamber.

[0014] Gas flow to the channels in which mixing takes place is controlled by flow controllers to determine the mix/concentration of gases in the channels. Particles could form as a result of the mixing in the channels detrimentally affecting the process.

[0015] Accordingly a need has arisen for a system of supplying reactant/dopant gases to a semiconductor processing chamber which overcomes these different problems.

[0016] According to the present invention, there is provided a method of supplying reactant gas to a substrate processing apparatus having walls with inner surfaces defining a processing chamber housing a susceptor supporting a substrate, the method comprising the steps of:

separately supplying first and second reactant gases flowing along first and second gas paths, respectively, to the processing apparatus; and mixing said first and second gases and causing the mixed gas to flow towards the substrate, wherein the chamber is divided into an upper and a lower portion by the susceptor, and wherein the first and second gas paths allow the first and second reactant gases to respectively flow into the upper (218a) and lower (218b) portions of the chamber, and the second reactant gas to flow from the lower to the upper cham-

ber so as to first mix with the first reactant gas in the upper portion (218) near to the substrate.

[0017] The details and advantages of the present invention will no doubt become apparent to those skilled in the art after having read the following detailed description of the preferred embodiments which is illustrated in the several figures of the drawing.

[0018] In the accompanying drawing:

Fig. 1 is a cross section of a prior art CVD semiconductor wafer processing chamber;

Fig. 2 is a cross section through the gas inlet manifold of an embodiment included for background interest only;

Fig. 3 is a plan view of a portion of a CVD processing chamber illustrating some of the components of the manifold of Fig. 2;

Fig. 4 is a pictorial exploded view showing some of the components of the manifold of Fig. 2;

Figs. 5(a) to 5(e) are cross sections of alternative embodiments to the manifold illustrated in Fig. 2;

Fig. 6 is a figure similar to that in Fig. 1 but showing schematically how gases can be supplied to the chamber to reduce back side wafer deposition in accordance with the present invention;

Fig. 7 is a plan view similar to that in Fig. 3 showing how the manifold can be divided to make allowance for different types of gas supply; and

Fig. 8 is a schematic flow diagram showing how different mixtures of gases can be regulated and supplied to an epitaxial deposition chamber.

[0019] Referring jointly to Figs. 2, 3 and 4, the improved gas inlet manifold, generally indicated as 100 can be seen. The manifold 100 is shown in Fig. 2 and 3 as connected to the side wall 14 (constituted by upper and lower clamp rings 40, 42 and a base ring 44) of a semiconductor processing apparatus.

[0020] In all three of these figures the manifold 100 is shown to include a connector cap 102, a diffuser plate 104 and an interface 106. The connector 102 and the interface 106 have upper and lower fluid passages 108, 110 formed therein. As is apparent from Fig. 4, these upper and lower fluid passageways are oblate in cross-section. The diffuser plate 104 on the other hand has an upper and a lower row of circular holes 112 formed therein. When the plate 104 is in position between the cap 102 and the interface 106, the upper and lower rows of holes 112 correspond respectively to the upper and lower fluid passages 108, 110. The function of these holes will be described further below.

[0021] The connector cap 102 is connected to a plurality of upper and lower gas conduits 114, 116. These conduits 114, 116 are, in turn, part of gas supply system (not shown) and serve to transport processing gases from a gas supply to the chamber 18. Along the inside wall of the chamber 18 a circular quartz ring 118 is dis-

posed. In the vicinity of the manifold 100, the quartz ring has an upper gas and lower gas passageways 120, 122 formed therein. These upper and lower gas passageways 120, 122 are aligned and communicate directly with the gas passageways 108, 110 formed in the interface 106. In the body of the quartz ring the lower gas passageway 122 is connected to the upper gas passageway 120 by means of a vertically disposed slot 124 which, when viewed in plan, defines an arc.

[0022] In operation, processing gas is supplied to the manifold 100 by means of conduits 114, 116. These gases are kept separate and flow respectively along upper and lower conduits 108, 110. As the gases are supplied from individual gas conduits 114, 116 to the upper and lower conduits 108, 110, individual streams of gases, each relating to one of the conduits 114, 116, occur in the connector cap 102.

[0023] These gases bank up against the up-stream side of the diffuser plate 104 and pass through the holes 112 formed therein. As a result of the diffuser plate, the gas streams respectively found in the upper and lower conduits 108, 110 are broken down and form a substantially laminar flow of gas in the interface 106. When the gas in the lower conduit 110 reaches the quartz ring 118 it moves along the lower gas path 122 and up the vertically disposed slot 124 to meet and mix with the gas in the upper conduit 108. At this point the gas has been heated to some extent by the quartz ring 118 which, in turn, has been heated by the lamps. As a result of this arrangement, the gas is preheated before mixing occurs and undesirable crystals do not form. This mixture of gas is then able to move in a substantially laminar pattern across the preheat ring 24, the susceptor 22 and the wafer 20 to be exhausted through the exhaust 36.

[0024] As can be seen from Figs. 3 and 4 the interface 106 has a flat upstream face 130 and a curved downstream face 132. This allows the interface 106 to provide a gas flow path between the flat faced connector cap 102 and diffuser plate 104 on the one hand and the circular quartz ring 118 on the other hand. In addition, Figs. 2 and 4 show that the diffuser plate 104 fits into a recess 134 formed in the connector cap 102. As a result of this configuration, the interface 106, which is typically made of quartz, abuts against both the diffuser plate 104 and the connector cap 102.

[0025] In Figs. 5a-5e different configurations of channels, generally indicated as 140 are shown formed in the quartz ring 119. These channels 140 all serve approximately the same function as the channels 120, 122 shown in Fig. 2 and these figures serve to illustrate a number of different configurations of channels that can be used to allow the mixing of the gases to occur as close as possible to the interior face of the quartz ring 118. Apart from the different configurations of the channels 140, all the other components shown in Figs. 5a-5e are identical to or similar to corresponding components illustrated in Figs. 2 through 4. Accordingly, they have been given like reference numerals.

[0026] The inlet manifolds illustrated in these Figures 2 to 5 therefore provide a solution to the problem of gases reacting spontaneously in the supply conduits and inlet manifold in the nitride deposition process described above. It will be understood that the principles illustrated in these figures could be applied to processes other than the nitride deposition process.

[0027] A embodiment of the method according to the present invention is illustrated using Fig. 6. This figure shows a typical CVD deposition chamber generally indicated as 210. As with the prior art deposition chamber 10 indicated in Fig. 1, the apparatus includes a top 12, side walls 14 and lower portion 16 which together define a processing chamber 218. Inside the chamber 218 a semiconductor wafer 20 is supported on a susceptor 22. A susceptor circumscribing preheat ring 24 is also shown. Processing gases are input from different sources (not shown) into the chamber 218 by way of input manifold 232 and are exhausted from the chamber by means of exhaust port 36. For clarity the heater lamps and other components of the apparatus are not illustrated.

[0028] As is apparent from this figure the preheat ring 24 and the susceptor 22 divide the chamber 218 into an upper and lower zone 218a and 218b respectively.

[0029] The method of the invention can be used to combat the undesirable reaction between ammonia and silicon species gases in the nitride deposition process. This can be done by injecting each gas from a different source separately into one of the upper or lower portion of the chamber 218 respectively through upper and lower passageways 232a and 232b. This means that the gases do not mix until they are fully inside the chamber 218.

[0030] For example, the silicon species gas can be injected into the upper zone 218a whilst the ammonia based gas can be input into the lower zone 218b. If the ammonia input into the lower zone 218b is at a slightly higher pressure than the silicon species gas input into the upper zone 218a, the ammonia gas will flow (in the direction indicated by arrows 222) from the lower zone to the upper zone by way of the slit between the preheat ring 24 and the susceptor 22 in the direction of the arrows 220. Thus both the ammonia gas and the silicon gas are heated within the chamber before they come into contact with one another. Furthermore, mixing of the gases occurs at or close to the wafer and unwanted particle formation is reduced.

[0031] The configuration shown in figure 6 also has the advantage that the gas moving through the slit between the preheat ring 24 and the susceptor 22 prevents gases from moving from the upper zone 218a to the lower zone 218b. This restricts the amount of deposition that occurs on the back side of the susceptor 22 and the other components within the lower zone 218b of the processing apparatus 210. It is important to restrict deposition on the back side of the susceptor as it may adversely affect temperature measurements (usually done

by means of an external pyrometer) which, in turn, will adversely affect processing of the wafer 20. Deposition on the other components in the lower zone 218b is undesirable as it could lead to particle generation if not removed. In addition, wafer transfer occurs in this lower zone 218b and substantial particle generation could adversely affect the moving parts in this zone.

[0032] The apparatus illustrated in figure 6 can also be used to reduce the problem (as described above) associated with doped polysilicon deposition. As will be recalled, the temperature dependence of dopant incorporation is opposite to the temperature dependence of the polysilicon deposition rate. The apparatus provides the flexibility of inputting the dopant gas into the lower zone 218b and being able to independently control its flow. Therefore an additional and independent source of control over dopant incorporation can be achieved.

[0033] The embodiment illustrated using Figure 6 can be used in conjunction with a further system of improving the control of different types of gases flowing into the processing chamber as illustrated in Figs. 7 and 8. These figures show only the interfacing connector 306, portions of the processing apparatus, the wafer 20, susceptor 22, preheat ring 24 and gas outlet port 36. Figure 7 shows only the portion of the gas inlet manifold 332 which supplies the gas to the upper zone of the processing chamber and Figure 8 schematically represents a gas control system.

[0034] The interfacing connector 306 is shown to be constituted by a central zone 308 and an outside zone 310. According to this embodiment of the invention and as further illustrated in Fig. 8, the composition of the gas which flows into the central zone 308 can be controlled independently of the composition of the gas which flows into the outside zones 310. In addition, the flow rate of the gas to either of the two halves 308a, 308b of the central zone can further be controlled independently from one another. This provides two degrees of control for the gas flow system for the purpose of controlling the composition of any layer deposited on the semiconductor wafer 20. In addition, the chamber heating system provides the third control variable (i.e., temperature). As in the past, the susceptor 22 can be rotated to improve the uniformity of the deposition on the wafer 20.

[0035] Turning now to the diagram in Fig. 8, it can be seen that a gas containing silicon, together with a hydrogen carrier gas are fed to the chamber 318 from containers 302, 304 by means of independent mass flow controllers 303, 305. This gas mixture flow through two bellows metering valves 311, 312 which operate as variable restricters and apportion the main flow of silicon bearing gas between the center and outer zones 308, 310 respectively. In addition, a gas which is a dopant source (such as diborane diluted in hydrogen) is fed from storage 314 into two different mass flow controllers 316, 320 and then metered into the silicon source downstream of the bellowing metering valves 311, 312.

[0036] As a result of this configuration, separate con-

trol of the dopant gas concentration flowing into the central zone and the outer zone 308, 310 respectively can be achieved.

Claims

1. A method of supplying reactant gas to a substrate processing apparatus having walls (14) with inner surfaces defining a processing chamber (218) housing a susceptor (22) supporting a substrate (20), the method comprising the steps of:

separately supplying first and second reactant gases flowing along first and second gas paths (232a, 232b), respectively, to the processing apparatus; and mixing said first and second gases and causing the mixed gas to flow towards the substrate (20), wherein the chamber is divided into an upper and a lower portion (218a, 218b) by the susceptor (22), and wherein the first and second gas paths allow the first and second reactant gases to respectively flow into the upper (218a) and lower (218b) portions of the chamber, and the second reactant gas to flow from the lower to the upper chamber so as to first mix with the first reactant gas in the upper portion (218a) near to the substrate.

2. A method according to claim 1, wherein the chamber includes a susceptor circumscribing ring (24) which defines an annulus between itself and the susceptor (22), the method further comprising the step of causing the second reactant gas to pass from the lower portion (218b) of the chamber through the annulus to mix with the first reactant gas in the upper portion (218a) of the chamber.
3. A method according to claim 2, wherein the susceptor circumscribing ring is a preheat ring (24).
4. A method according to any one of the preceding claims, further comprising the step of controlling the flow of gas in at least one path (232a, 232b), so that the flow through a central zone (308) in relation to the substrate is controlled separately from the flow through an outside zone (310).
5. A method according to claim 4, wherein the flow through the central zone is split into two halves (308a, 308b) and the method further comprises controlling the flow through the two halves independently from one another.

Patentansprüche

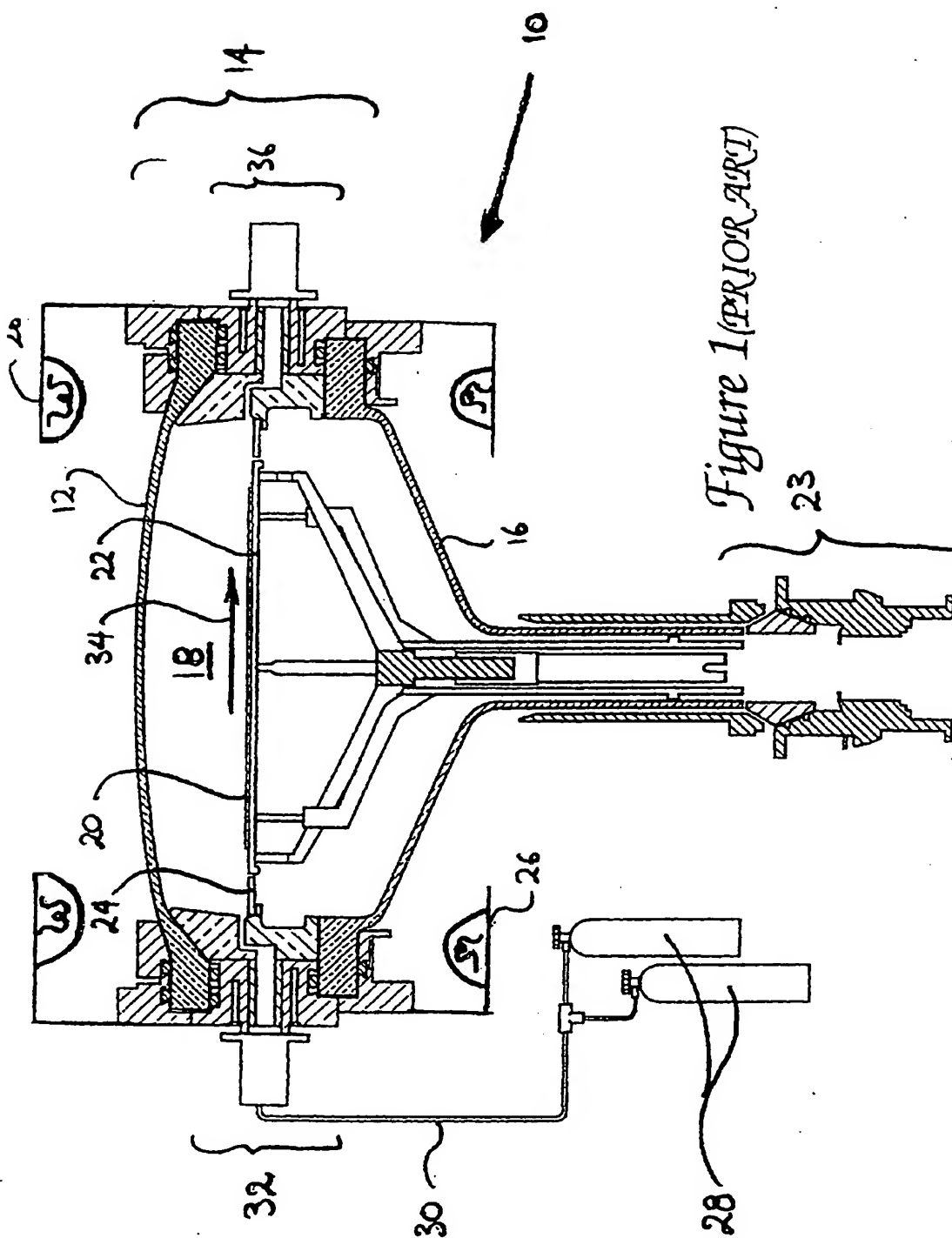
1. Verfahren zum Zuführen von Reaktionsteilnehmer-

gas zu einer Substratbehandlungsvorrichtung, die Wände (14) mit Innenflächen hat, die eine Behandlungskammer (218) begrenzen, die einen ein Substrat (20) tragenden Suszeptor (22) aufnimmt, wobei das Verfahren die Schritte aufweist:

- gesondertes Zuführen eines ersten und eines zweiten Reaktionsteilnehmergeases, die längs eines ersten beziehungsweise zweiten Gaswegs (232a, 232b) zu der Behandlungsvorrichtung strömen, und
 - Mischen des ersten und zweiten Gases und Strömenlassen des gemischten Gases zu dem Substrat (20),
 - wobei die Kammer durch den Suszeptor (22) in einen oberen und einen unteren Abschnitt (218a, 218b) unterteilt ist, und
 - wobei der erste und zweite Gasweg es ermöglicht, dass das erste und zweite Reaktionsteilnehmergeas jeweils in den oberen Abschnitt (218a) und unteren Abschnitt (218b) der Kammer strömt und dass das zweite Reaktionsteilnehmergeas aus der unteren zur oberen Kammer so strömt, dass es sich erst mit dem ersten Reaktionsteilnehmergeas im oberen Abschnitt (218a) nahe an dem Substrat vermischt.
2. Verfahren nach Anspruch 1, bei welchem die Kammer einen den Suszeptor umgebenden Ring (24) aufweist, der einen Ringraum zwischen sich und dem Suszeptor (22) begrenzt, wobei das Verfahren weiterhin den Schritt aufweist, das zweite Reaktionsteilnehmergeas dazu zu bringen, von dem unteren Abschnitt (218b) der Kammer durch den Ringraum hindurchzugehen, um sich mit dem ersten Reaktionsteilnehmergeas im oberen Abschnitt (218a) der Kammer zu vermischen.
 3. Verfahren nach Anspruch 2, **dadurch gekennzeichnet, dass** der den Suszeptor umgebende Ring ein Vorheizring (24) ist.
 4. Verfahren nach einem der vorhergehenden Ansprüche, welches weiterhin den Schritt aufweist, den Gasstrom in wenigstens einem Weg (232a, 232b) so zu steuern, dass der Strom durch eine zentrale Zone (308) bezogen auf das Substrat getrennt von dem Strom durch eine Außenzone (310) gesteuert wird.
 5. Verfahren nach Anspruch 4, bei welchem der Strom durch die zentrale Zone in zwei Hälften (308a, 308b) aufgeteilt wird und das Verfahren weiterhin ein Steuern des Stroms durch die beiden Hälften unabhängig voneinander aufweist.

Revendications

1. Procédé d'alimentation en gaz réactionnel d'un appareil de traitement de substrat ayant des parois (14) présentant des surfaces intérieures définissant une chambre de traitement (218) logeant un suscepteur (22) supportant un substrat (20), le procédé comprenant les étapes qui consistent :
à fournir séparément des premier et second gaz réactionnels s'écoulant suivant des premier et second trajets de gaz (232a, 232b), respectivement, à l'appareil de traitement ; et à mélanger lesdits premier et second gaz et amener le gaz mélangé à s'écouler vers le substrat (20), dans lequel la chambre est divisée par le suscepteur (22) en parties supérieure et inférieure (218a, 218b), et dans lequel les premier et second trajets de gaz permettent aux premier et second gaz réactionnels de s'écouler respectivement jusque dans les parties supérieure (218a) et inférieure (218b) de la chambre, et au second gaz réactionnel de s'écouler de la chambre inférieure à la chambre supérieure afin de se mélanger d'abord avec le premier gaz réactionnel dans la partie supérieure (218a) à proximité du substrat.
2. Procédé selon la revendication 1, dans lequel la chambre comprend un anneau (24) entourant le suscepteur, qui définit un espace annulaire entre lui-même et le suscepteur (22), le procédé comprenant en outre l'étape qui consiste à faire passer le second gaz réactionnel depuis la partie inférieure (218b) de la chambre à travers l'espace annulaire pour qu'il se mélange au premier gaz réactionnel dans la partie supérieure (218a) de la chambre.
3. Procédé selon la revendication 2, dans lequel l'anneau entourant le suscepteur est un anneau (24) de préchauffage.
4. Procédé selon l'une quelconque des revendications précédentes, comprenant en outre l'étape qui consiste à commander l'écoulement de gaz dans au moins un trajet (232a, 232b), afin que l'écoulement à travers une zone centrale (308) par rapport au substrat soit commandé séparément de l'écoulement à travers une zone extérieure (310).
5. Procédé selon la revendication 4, dans lequel l'écoulement à travers la zone centrale est divisé en deux moitiés (308a, 308b) et le procédé comprend en outre la commande de l'écoulement dans les deux moitiés indépendamment l'une de l'autre.



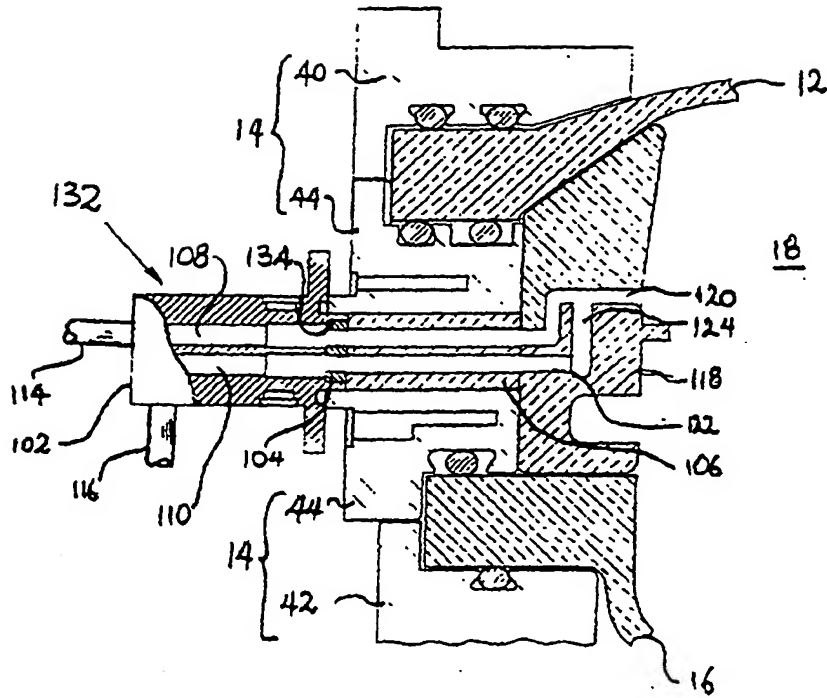


Figure 2

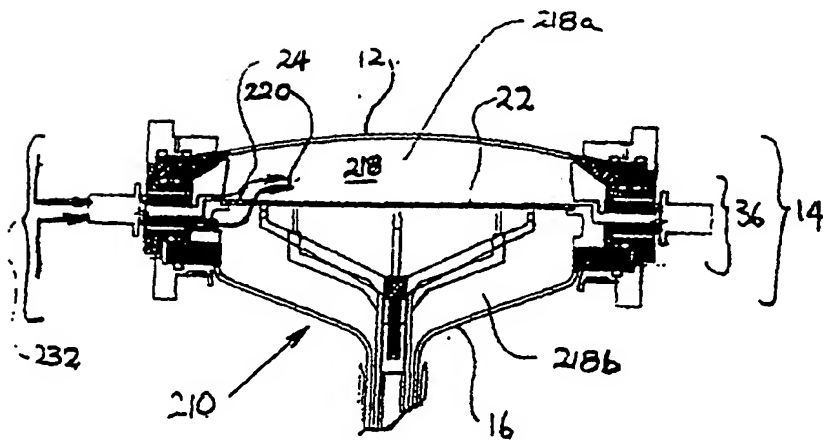
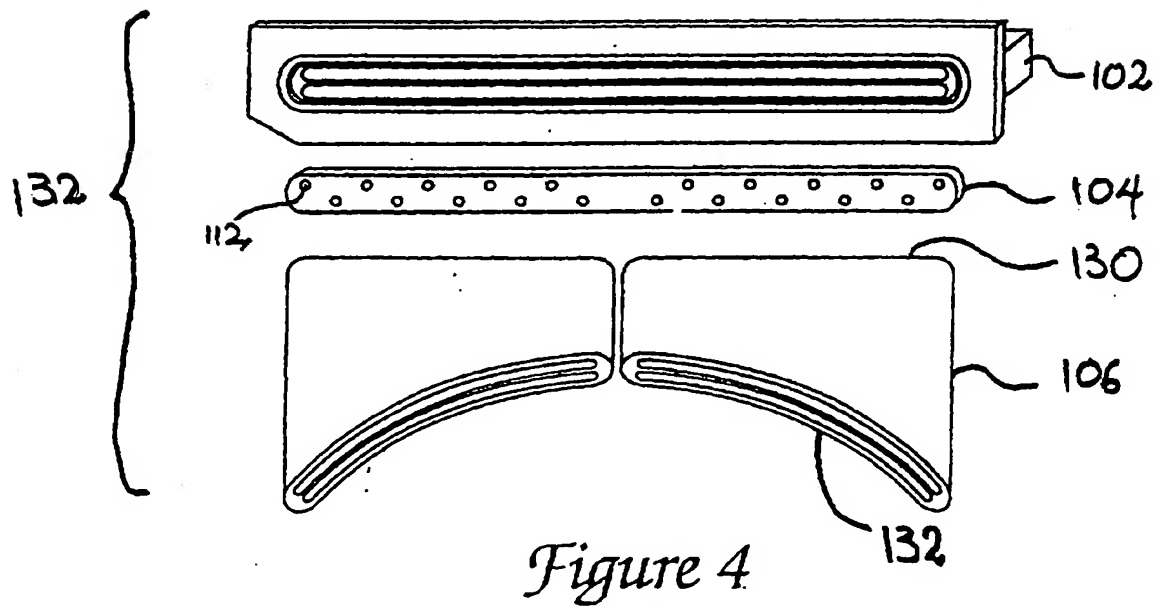
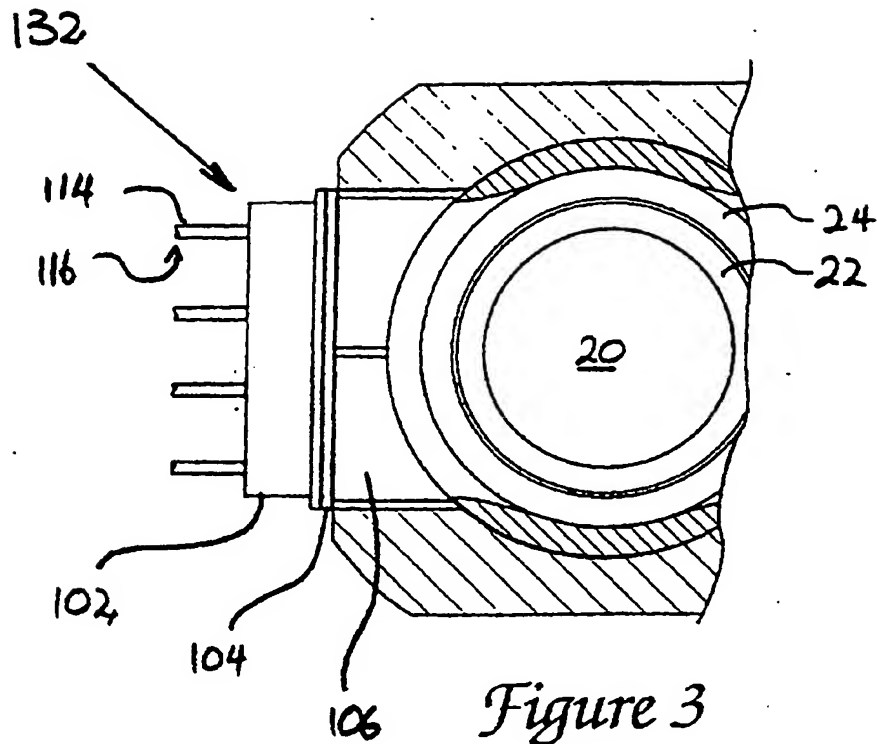


FIGURE 6



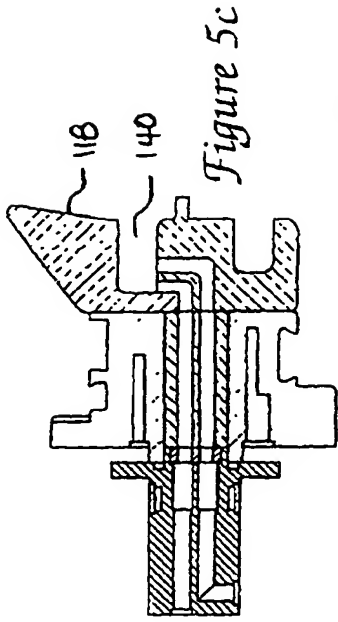


Figure 5c

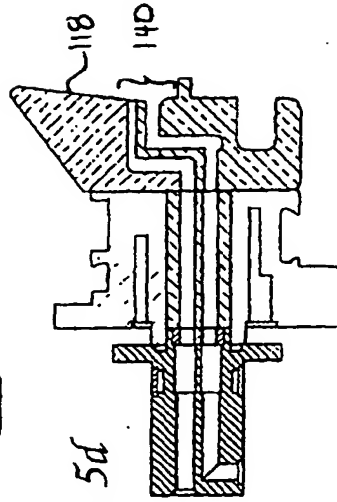


Figure 5d

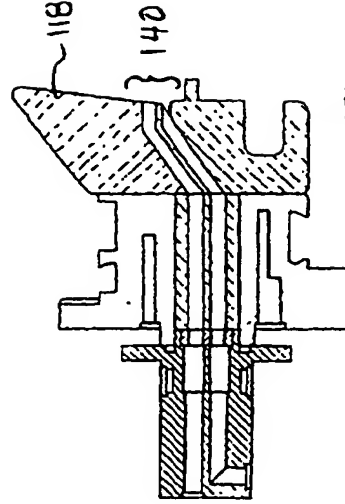


Figure 5e

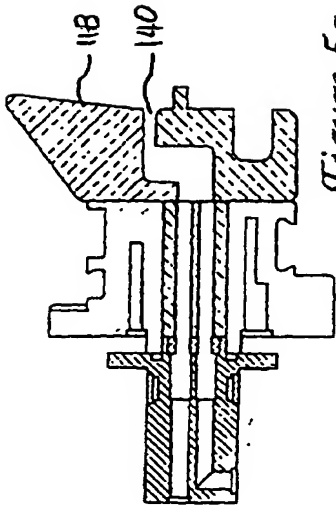


Figure 5a

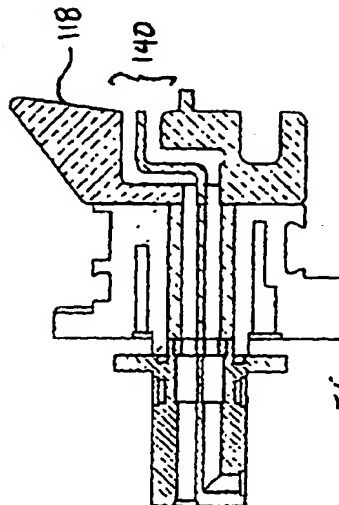


Figure 5b

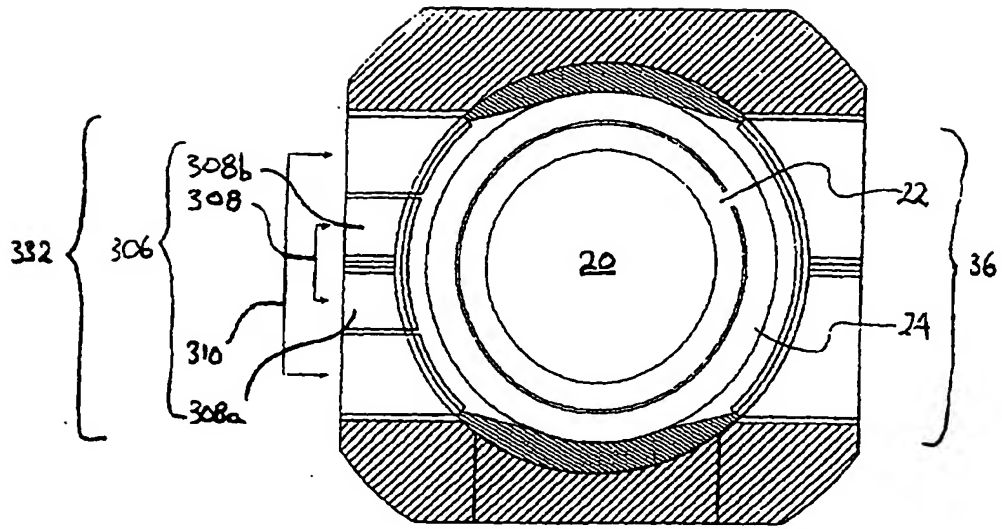


Figure 7

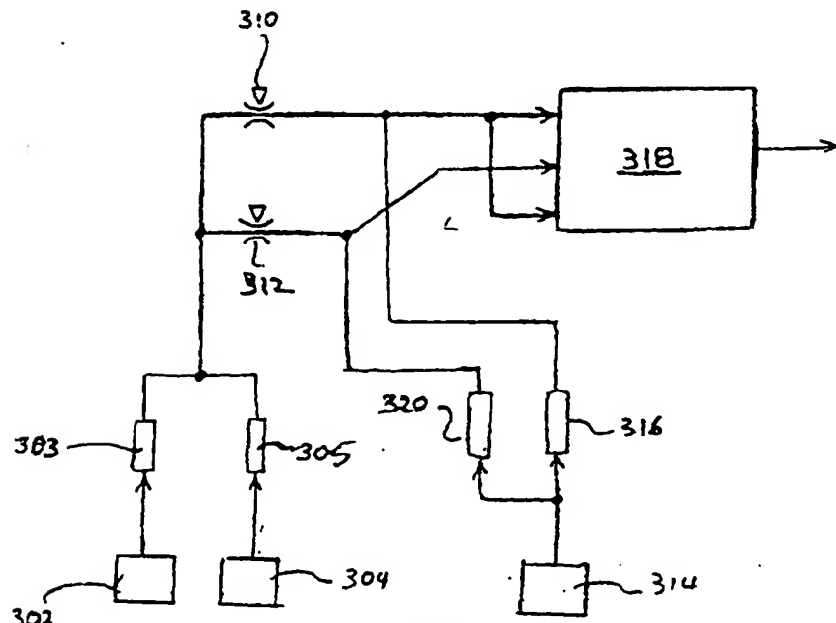


FIGURE 8